Remote Seabed Sediment Classification And Sediment Property Estimation Using High Resolution Reflection Profiles

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LONG-TERM GOAL

The long-term goal of this program is to develop normal incidence FM acoustic reflection techniques for remotely measuring the physical and acoustic properties of ocean sediments and to improve our understanding of seabed acoustics.

OBJECTIVES

- Develop signal processing techniques for inverting normal incidence acoustic data to calculate vertical profiles of acoustic and physical properties such as acoustic impedance, compressional wave attenuation, bulk density, mean grain size, etc.
- Determine interrelationships between directly measured acoustic properties and other acoustic and physical properties such as sound velocity, shear strength, grain size, porosity, gas concentration.
- Develop acoustic models of sound interacting with the seafloor to provide a theoretical basis for signal processing techniques and property interrelationships.

APPROACH

In order to achieve our goal of automated sediment property prediction, we have developed several signal processing techniques for estimating the geoacoustic properties of the seabed. Those signal processing procedures use expert knowledge, fuzzy logic and genetic algorithms to provide inverse solutions that work well under adverse conditions. We collect normal incidence acoustic data over a wide range of depositional environments and calculate vertical profiles of acoustic and physical property and compare those profiles with insitu and core data. Drs LeBlanc and Schock supervise the research which is conducted by graduate and undergraduate students. Vincent Freyermuth, who completed his Master's of Science degree in August 1998, developed a neural network approach to finding the interfaces of sediment layers in chirp subbottom images. Earnest Arizzi, an undergraduate student assisted in offshore experiments.

WORK COMPLETED

During the past year, we developed a new technique for generating high resolution imagery and chirp sonar data with a bandwidth in excess of I decade. The technique allows simultaneous transmission of

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chirp pulses out of several transducers where each transducers cover a different operating frequency band. The resolution of subsurface images has increased substantially using this multi-band technique. The multiple chirp pulses add linearly in the water and effectively simulate a band-limited impulse response that has a bandwidth that is much wider than that generated by a single transducer. A calibration technique has been developed that allows the reflection coefficient of the seabed to be measured as a function of frequency. The added bandwidth provides greater reliability in making estimates of compressional wave attenuation from interlayer reflectors.

RESULTS

The resolution achieved using multi-band pulses can be seen in Figure 1. Vertical resolution was better than 10 cm.

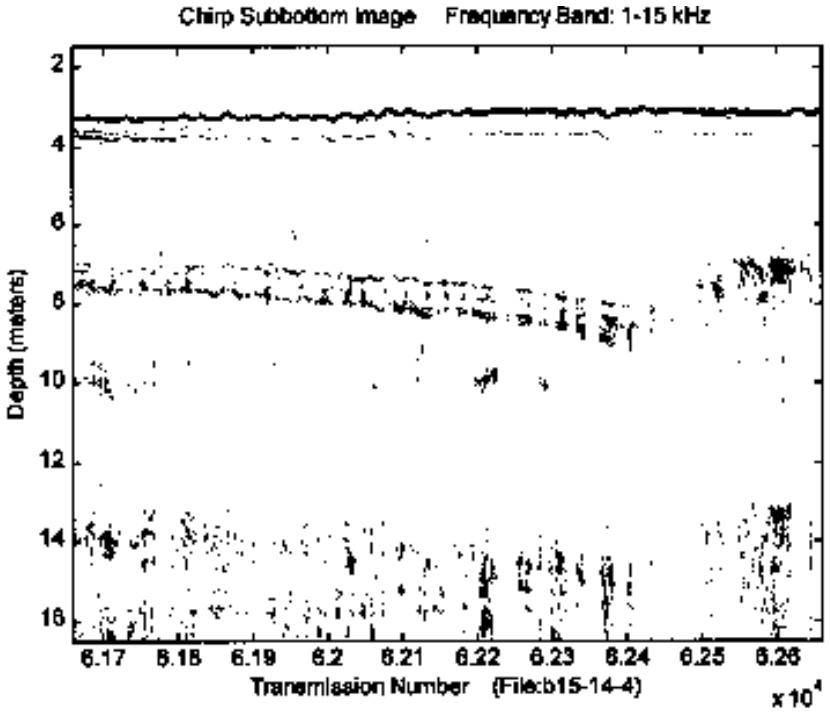

Figure 1: Multiband chirp sonar image

Multiband processing of the chirp data improved the accuracy of sediment property prediction substantially. Chirp sonar data with a band of 1.7 to 12 kHz, collected along the Chesapeake Bay Bridge Tunnel, was analyzed to show that increasing the acoustic bandwidth from 1 octave to 2 octaves substantially reduced the error in calculating the phase of subsurface reflectors and that multiband processing allowed identification and rejection of the acoustic reflections that contained interference from inversion calculations. The technique consistently allowed the correct identification of a sandy silt layer that was 5 meters under a silty sand layer at a Chesapeake Bay Bridge tunnel boring site. Figure 2 is a subbottom image taken at the boring site. The subsurface layers in the image were automatically detected with a fuzzy pattern recognition algorithm. The amplitude and phase of the subbottom reflection were used to calculate the impedance of the sediment layers. The spectrum of the subsurface reflections were compared to obtain the attenuation coefficient, the slope of the attenuation function.

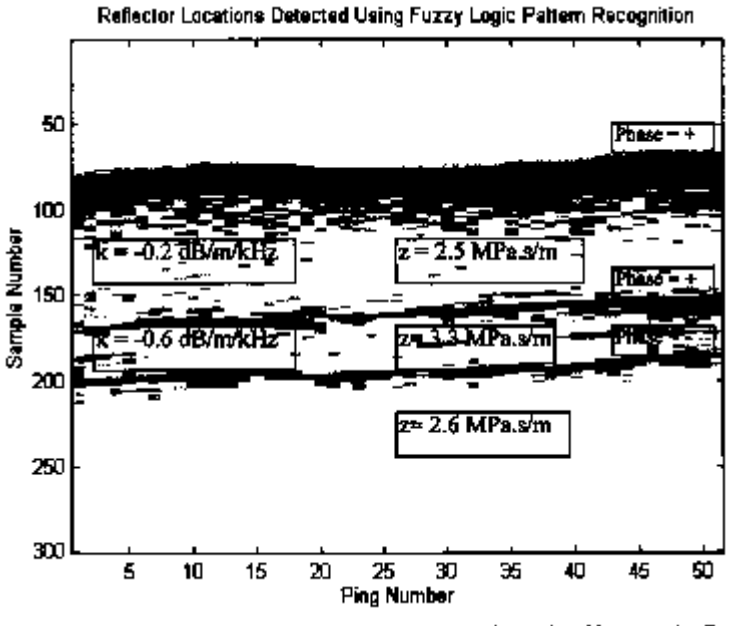

Figure 2 Subbottom image acquired at a boring site along the Chesapeake Bay Bridge Tunnel. Predictions of the attenuation coefficient and sediment impedance agree with the siltsand-silt sequence of sediment layers.

IMPACT/APPLICATIONS

Sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying the top 10 meters of the seabed and obtaining vertical profiles of attenuation, acoustic impedance, volume scattering. From these acoustic property profiles, vertical profiles of physical properties such as bulk density, grain size, and porosity can be estimated.

TRANSITIONS

The chirp sonar, which evolved out of this program, was transitioned to industry in the early 1990s and has become the standard ocean industry instrument for conducting high resolution ocean surveys. The transition of sediment classification procedures to industry (Edgetech, formerly EG&G Marine Instruments) was completed in February 1996. Edgetech has provided an alpha (preliminary) release of the software to FAU for testing. The sediment classification technology is currently being transitioned to NAVFAC via a SBIR for the purpose of providing the Navy with rapid seabed assessment capability for amphibious forces. The first two multi-band chirp sonars are being used by NAVFAC and Woods Hole Oceanographic Institution.

RELATED PROJECTS

Core data for this project has been provided by the Coastal Benthic Boundary Layer Program (Dr. Richardson) and NFESC (H. Herrmann).

PUBLICATIONS

1. “Acoustic classification of subsurface sediment layers using multi-feature pattern recognition and least squares inversio” S. G. Schock and H. G. Herrmann, Ocean Community Conf. 98, Nov 17,1998.